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THE OCEANOGRAPHIC PROGRAM FOR THE ARCTIC ICE DYNAMICS JOINT EXPERIMENT

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ABSTRACT

During the 1975-6 program of the Arctic Ice Dynamics Joint Experiment (AIDJEX), observations of currents, temperature and salinity will be made in the upper layers of the Arctic Ocean. The primary objective is determination of water stress on drifting ice, one of the parameters in the numerical ice drift model being developed under the AIDJEX program. The oceanographic observations will be made at an array of four manned drift stations with separations of 100 km. Simultaneous measurements will be made at all four stations. Continuous current observations will be made at depths of 2 and 30 m. Current profiles from the surface to a depth of 200 m will be taken twice each day. Profiles of temperature and salinity will be taken twice each day also from the surface to 1,000 m with Plessey salinity-temperature-depth recorders.

"From the drifting ice all movements of the water - the horizontal currents as well as ... vertical oscillations of the layers - may be continually and carefully studied at all depths in an ideal manner which is not possible in the open ocean; and many of the greatest problems of oceanography may thus be solved."

-Fridtjof Nansen, 1928

Introduction

Sea ice varies greatly in seasonal extent, covering the entire Arctic Ocean during winter months but shrinking to cover only 60% of the ocean during summer. On the geological time scale even larger changes have taken place.

It has been shown that polar waters (less than 0.5°C) of the North Atlantic during the Wisconsin ice advance. This implies a much greater sea ice coverage during that period. (Ruddiman and McIntyre, 1973). Moreover sea ice has a large potential for changing climate through its high albedo, reflecting up to about 75% of incoming radiation in contrast to only 10 or 20% for open water. Thus radiation exchange in the polar regions is drastically changed by the presence or absence of pack ice. This change in ice extent and its importance to the radiation balance suggest the possibility that it has a role in feedback processes leading to climatic change.

Little is known about the behavior of sea ice on a large scale. The opening of leads and production of pressure ridges introduces complications beyond the simpler behavior of a homogeneous ice sheet. The Arctic Ice Dynamics Joint Experiment is a study of large-scale interaction between ice, ocean and atmosphere designed to give better understanding of sea ice behavior. The aim of the experiment is to use data on ice stress and strain, gathered from a multi-station array, to formulate a dynamic ice model. The results should ultimately lead to a predictive sea ice model which can be coupled with numerical global atmospheric and oceanic models to more closely represent the behavior of the fluid earth. (Maykut et al, 1972)

The water stress on the bottom of the ice must be measured and, together with wind stress and body forces on the ice, must be related to the motion of the pack to give a stress-strain rule. One of the goals of the AIDJEX oceanographic program is to measure water stress as a function of time over a manned array, consisting of four stations about 100 km apart, which will be occupied during 1975-76. Oceanographic observations at the manned camps will consist of current, temperature and salinity from which stress will be determined according to several theoretical models. The primary aim is to develop a way to derive water stress from simple parameters without oceanographic measurements.

Water stress is generally a drag force on the ice. Momentum flows downward from the wind to the ice and then to the ocean. Momentum flux is downward through the base of the ice into the oceanic boundary layer where the energy is eventually dissipated as heat. The planetary boundary layer within which this frictional loss occurs may be considered to consist of two parts: a surface layer just below the ice which is about two meters thick and an Ekman layer below that which is about 25 m thick. Observations will be concentrated in the Ekman layer although not restricted to it. The planetary boundary layer in the Arctic Ocean is much more accessible than the atmospheric boundary layer above the ice which has a height well above the reach of towers(about 1000 m.) Instruments may be deployed throughout the relatively thin oceanic boundary layer to measure the momentum change in a fairly complete manner. Opportunity will

be taken of this and stress will be principally measured with a momentum integral technique (Hunkins, 1974).

Offsetting the observational advantage of shallow depth in the oceanic boundary layer is the fact that the keels of pressure ridges may on occasion extend through an appreciable fraction of the planetary boundary layer. This presents a sampling problem since there will not be enough instrument arrays to sample statistically in space. Representative instrument sites must be selected. In addition some assessment of the keel drag must be made separately and coupled with ridge frequency statistics.

In addition to measuring stress the experiment will sample many phenomena of basic oceanographic importance.

Observations from the manned stations will provide a one-year set of data over a 100-km array. Systematic data on currents, temperature and salinity from arrays of any scale are rare in the oceans. There is no world network of continuous observational stations for the oceans such as the meteorologists have for the atmosphere. It has become increasingly evident that time-dependent motions are of importance to ocean circulation and mixing. The AIDJEX array provides a unique opportunity to study motions with horizontal scales of 100 km, vertical scales of 1000 m or less and time scales less than one year.

Some of the phenomena investigated, such as mixed layer dynamics, relate directly to the stress problem. The mixed layer is well developed in winter and spring by brine convection induced by the freezing ice sheet. Conditions change in the summer

as meltwater empties into leads and holes through the ice to produce a statically stable water column. Summer conditions are little known and the effect of stable conditions on water stress is still undetermined. In addition to the flux of momentum, the fluxes of mass, heat and salt in the mixed layer may be determined. The horizontal mass flux in the mixed layer may be measured directly over the array and checked against indirect mass divergence calculations based on the stress observations. If the observations of stress differences over the array are sufficiently accurate it will be possible to measure stress vorticity which should balance mass divergence in the Ekman layer. Mass divergence found independently from mixed layer thickness can thus provide a check on the direct stress observations.

Still other phenomena such as baroclinic eddies and internal waves are not clearly related to stress but the array of instruments mounted on the stable ice platform provides a fine opportunity for their study. Baroclinic eddies in the Arctic Ocean were first clearly documented during the 1972 AIDJEX pilot program (Hunkins, 1974; Newton and Coachman, 1974). The eddies have diameters of 10 to 20 km with current speeds reaching 40 cm/sec. They are restricted to a limited depth range between 50 and 300 m. These eddies are believed to originate in baroclinic instability associated with the mean shear between the Pacific and Atlantic water masses which intrude into the Arctic Ocean from opposite sides. The role of the eddies in large-scale mixing of heat, salt and momentum is still not un-

derstood. More statistics on size and numbers are needed. The AIDJEX results should provide such statistics. It may be possible to track one or more of these eddies across the array long enough to measure its decay rate. The array spacing was specifically designed to sample the synoptic meteorological scale since this is the scale of wind-driven ice drift. The eddy problem requires an array with a finer mesh, say 5 or 10 km. Tentative plans are being developed for such an array to be deployed in late 1975.

The AIDJEX oceanographic plan was designed to meet its scientific objectives within the limitations imposed by the field conditions, manpower and funding. The instruments are generally types which have been used before and can be expected to operate accurately for a year under harsh conditions if operated with care and thought. Although spares have been stocked there are no replacements for complete systems and the program depends upon the skill and industry of its technicians and scientists in keeping the program running as continuously s apossible. The importance of continuity in the data should be emphasized.

Changes to the oceanographic plan will undoubtedly occur and it is expected that there will be revisions to the present plan in the future.

Observational Program

Identical routines of current, salinity and temperature measurements will be followed at all four manned stations to insure a uniform set of data. In addition, certain additional observations will be taken at the main camp.

Basic Program

Currents -

1/ Continuous recording at depths of 2 and 30 m below the base of the ice. Savonius rotor current meters will be mounted on individual rigid masts with signals carried to the surface by conducting cable. Current direction in these meters is referenced to the instrument case. The instruments are connected to fiberglass poles and referenced to the ice floe itself. Floe azimuth will be determined by the AIDJEX NAVSAT system. Signal processors will provide 0-1 V analog output for speed and direction. These signals (4 channels) will be amplified for input to the AIDJEX data logger which requires 0-5 V. The analog signals will be recorded on multipoint servo chart recorders. The accuracy is expected to be ± 3% of reading for speed and ± 1% full scale for direction for currents above 2½ cm/sec.

2/ Profiles from surface to 200 m will be taken twice-daily at 0600 and 1800 GMT. Profiling current meters (PCM) will be raised and lowered on conducting cable with electric winch. Signal processors will provide 10 mV output for speed, direction and depth. These will be amplified for input (6 channels) to the AIDJEX data logger. Analog signals will be recorded on XXXY re-

corders. Current direction will be referenced to magnetic north. Accuracy is expected to be ± 3 cm/sec for speed and ± 6° for direction for currents above 4 cm/sec. Surveyor's compasses will be read daily to establish magnetic declination.

Salinity and temperature -

Salinity-temperature-depth casts from surface to 1000 m will be made twice-daily at 0600 and 1800 GMT with Plessey Model 9040 STDs. Data will be recorded with XXY chart recorder and also on magnetic tape with Plessey Model 8400 digital data loggers.

The STD profiles will be calibrated with Nansen bottles and reversing thermometers. One bottle with paired thermometers will be mounted just above the STD sensor and tripped at a given depth. This depth will normally be increased by 100 m per day to repeat again after 10 days. On certain occasions the oceanographer-in-charge (OIC) may decide to change the bottle depth and this will be indicated by a message to all stations. A second bottle and thermometer pair will be reversed at a depth of 2 m beside the STD sensor as it soaks prior to lowering. Thermometer pairs will be changed at intervals. STD accuracies are ± 0.02°C in temperature, ± 0.02‰ in salinity and 0.25% of full scale in depth.

Additional observations

1/ At the Main Camp a deep STD cast will be taken weekly. A rosette sampler will be used to provide calibrating samples and thermometer readings at a number of depths.

2/ At the Main Camp a second fixed current meter system

with sensors at 2 and 30 m will be located at a site with ice roughness different from the first site to provide a measure of current variability under different ice conditions.

3/ Special days with increased rates of data collection may be declared by the OIC when storm conditions or the presence of eddies indicates that they will be valuable. On these special days the number of PCM and STD profiles will be doubled so that they occur every 6 hours. In the case of storm alerts, the depth may be reduced to 100 m for the extra casts. The OIC will provide notice to all stations clearly defining the extra measurements.

Calibration and Intercomparison of Instruments

The ultimate product of all the effort involved in the field program is a data set which is as accurate and reliable as possible. The type of instrumentation was chosen with this aim in mind. The quality of the data depend upon the care in operation and calibration exercised by the oceanographers.

Current Meters - The current meters are all of the Savonius rotor type with directional vane. This type has become standard in oceanographic research over the past few years and, while it has certain limitations, many of its characteristics are fairly well known (e.g. Gaul et al, 1963; Karweit, 1974). Tests have shown that the current speed is directly proportional to rotor revolutions beyond some critical speed of about 2 cm/sec, and that the linear calibration curve variation between instruments is not generally significant where reasonable manufacturing quality has been maintained and the bearings properly adjusted.

The Savonius rotors should be checked for a free fit in the bearings whenever raised or lowered. The rotor spin-down time in air should be logged.

Deck electronics for the current meters will be calibrated weekly by injecting square waves of known frequency and known resistances to simulate rotor pulses and direction signals. These checks will calibrate the entire system with the exception of the sensors themselves. A standard set of frequencies and resistances will be introduced, logged, and their readings on the panel meters and chart record noted. The calibration signals will also be recorded on the digital records.

Not all of the sensors will be calibrated directly in a tow tank. The results of previous tow tank tests on a few instruments will be accepted as applicable to all of the instruments. This assumption has been generally used in research with Savonius rotor instruments. However, the AIDJEX current meters will be intercompared to check their relative speed curves. One Savonius rotor current meter will be selected as a standard and will be periodically carried to each satellite camp and operated beside the 2 and 30 m instruments at those camps for a long enough period so that the currents cover a range of speeds. This standard instrument will have its own mast.

STDs - All STD casts will be accompanied by reversing bottle samples and thermometer readings to insure accuracy as has been described previously. The reversing thermometers were calibrated at the Pacific Northwest Regional Calibration Facility of NOAA.

Standard oceanographic practice will be observed in the field to insure their proper functioning and continued accuracy. All readings will be made with paired thermometers and the pairs will be changed periodically to build up a relative history. The water samples will all be taken to the main camp for salinity analysis. Special care will be taken to insure that they do not freeze en route. The samples will be analyzed with a Guildline lab salinometer with expected accuracy of better than 0.003‰ . Absolute salinity will be calibrated against standard and sub-standard sea water.

DATA MANAGEMENT

All important measurements will be recorded digitally so that extensive analyses may be conveniently carried out. Analog chart records taken simultaneously will be used only for monitoring data quality and for field analysis.

The current data will be recorded on the AIDJEX data logger which has a 10-bit resolution and a sampling rate of 2 per minute. The magnetic tapes will be taken to Seattle where the current meter data will be stripped off and placed on another tape for forwarding to Lamont. At Lamont these tapes will be checked for quality and errors and calibration corrections will be applied. The tapes will then be ready for analysis.

Copies of all reduced STD and CM data will be stored in the AIDJEX data bank. All original data including magnetic tapes and chart records and log books will reside in the Lamont archives.

Data Analysis

Field analysis - The oceanographer at each camp will inspect the record from each STD and PCM cast and the continuous CM record for any unusual features and try to assess whether they are natural or represent an instrumental problem. Close communication between main and satellite stations is important to help control data quality and to detect unusual phenomena.

Each satellite oceanographer will keep a log and report daily to Main Camp on the following measurements at the twice-daily stations.

1/ Current speed and direction at 2 and 30 m from field camp.

2/ Maximum current speed and direction and its depth on PCM.

3/ Current speed and direction at 200 m on PCM.

4/ T, S and depth of mixed layer.

5/ Depth and value of maximum T (Pacific and Atlantic Water Mass cores).

OCEANOGRAPHIC INSTRUMENTS

Satellite stations

1 PCM with winch, cable, deck unit and L & N XXXY chart recorder (shares 12' x 12' hut with fixed c. m.).

1 Plessey model 9040 serias 5300 STD (3000 m depth sensor) with winch, 1000 m cable, deck unit,L & N XXY chart recorder and Model 8400 DDL (occupies 12' x 12' hut).

2 Hydro Products geodetic Savonius Rotor current meters with deck unit, Speedomax multipoint servo chart recorder, cable and masts (shares 12' x 12' hut with PCM).

6 Deep-sea reversing thermometers

3 Nansen bottles w/thermometer frames, messengers, thermometer reader, sample bottles.

1 Surveyor's compass

1 Oscilloscope

1 Frequency counter

1 Decade resistance box

1 Frequency generator

1 Digital VOM

Main Camp

Same as at satellite with the following changes and additions:

Huts will be 12' x 16'
Model 9040 STD will have 4000 m of cable and depth sensor for 6000 m.

1 Rosette sampler and deck unit

(6 total) Hydro Prod. C. M. 2 for basic mast, 2 for extra mast, and 2 spares (4 extra)

(15 total) Deep-sea reversing thermometers (9 extra)

1 Guildline Model 8400 laboratory salinometer

2 Frequency generators

Standard Sea Water ampules

REFERENCES

Gaul, R. D., J. M. Snodgrass and D. J. Cretzler, "Some dynamical properties of the Savonius rotor current meter" *in* Marine Sciences Instrumentation vol. 2, 195 pp., Plenum Press, N. Y. 1963.

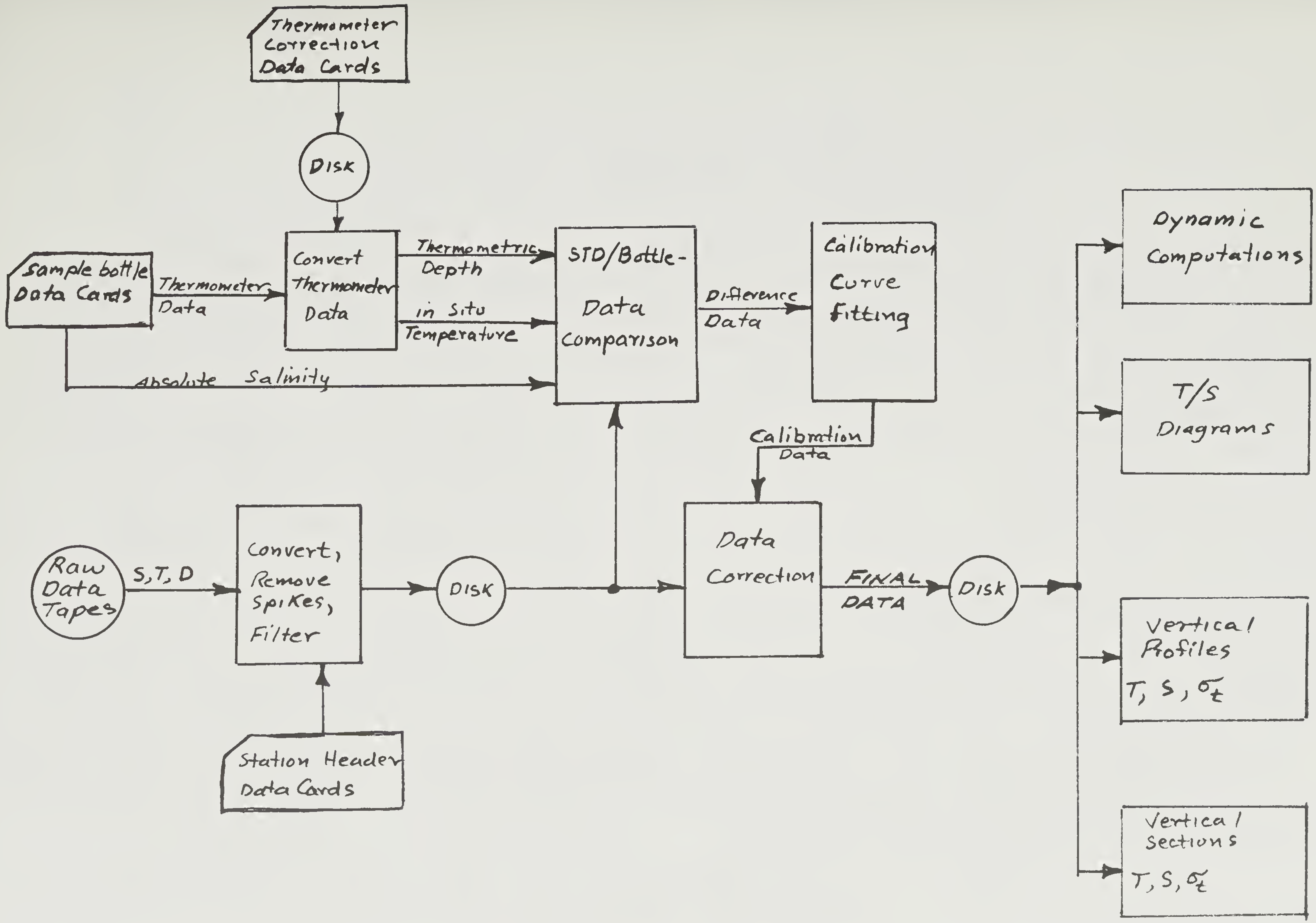
Hunkins, K., "The oceanic boundary layer and ice-water stress during AIDJEX '72," AIDJEX *Bull.* *26*, Sept. 1974.

Hunkins, K., "Subsurface eddies in the Arctic Ocean," Deep-Sea Research, *21*, 1017-1033, 1974.

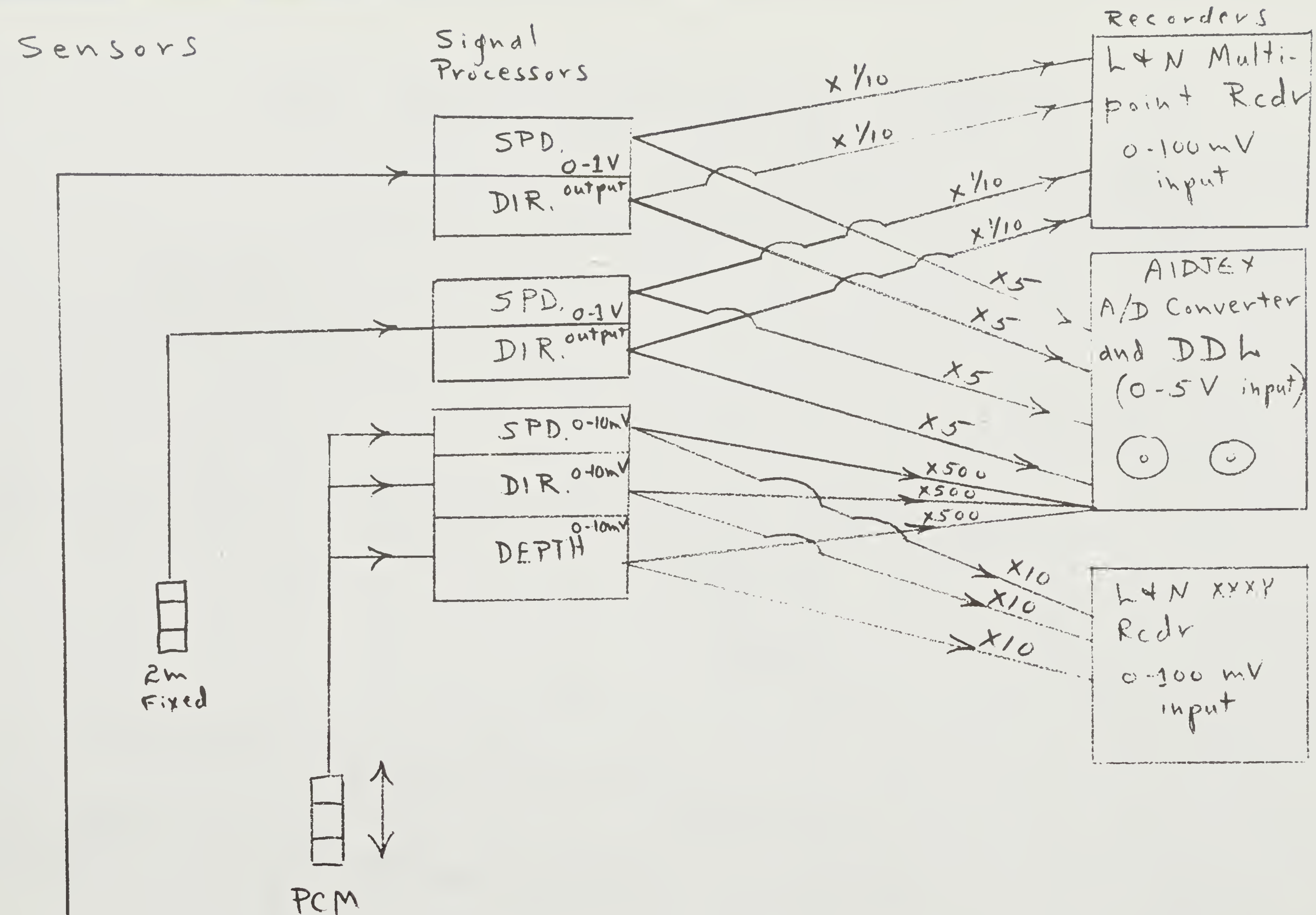
Karweit, M., "Response of a Savonius rotor to unsteady flow," *J. Mar. Res.* *32*, 359-364, 1974.

Maykut, G. A., A. S. Thorndike and N. Untersteiner, *AIDJEX Scientific Plan*, AIDJEX Bull. No. 15, 67 pp. Aug. 1972.

Newton, J. L., K. Aagaard and L. K. Coachman, "Baroclinic eddies in the Arctic Ocean", *Deep-Sea Res.*, *21*, 707-720, 1974.

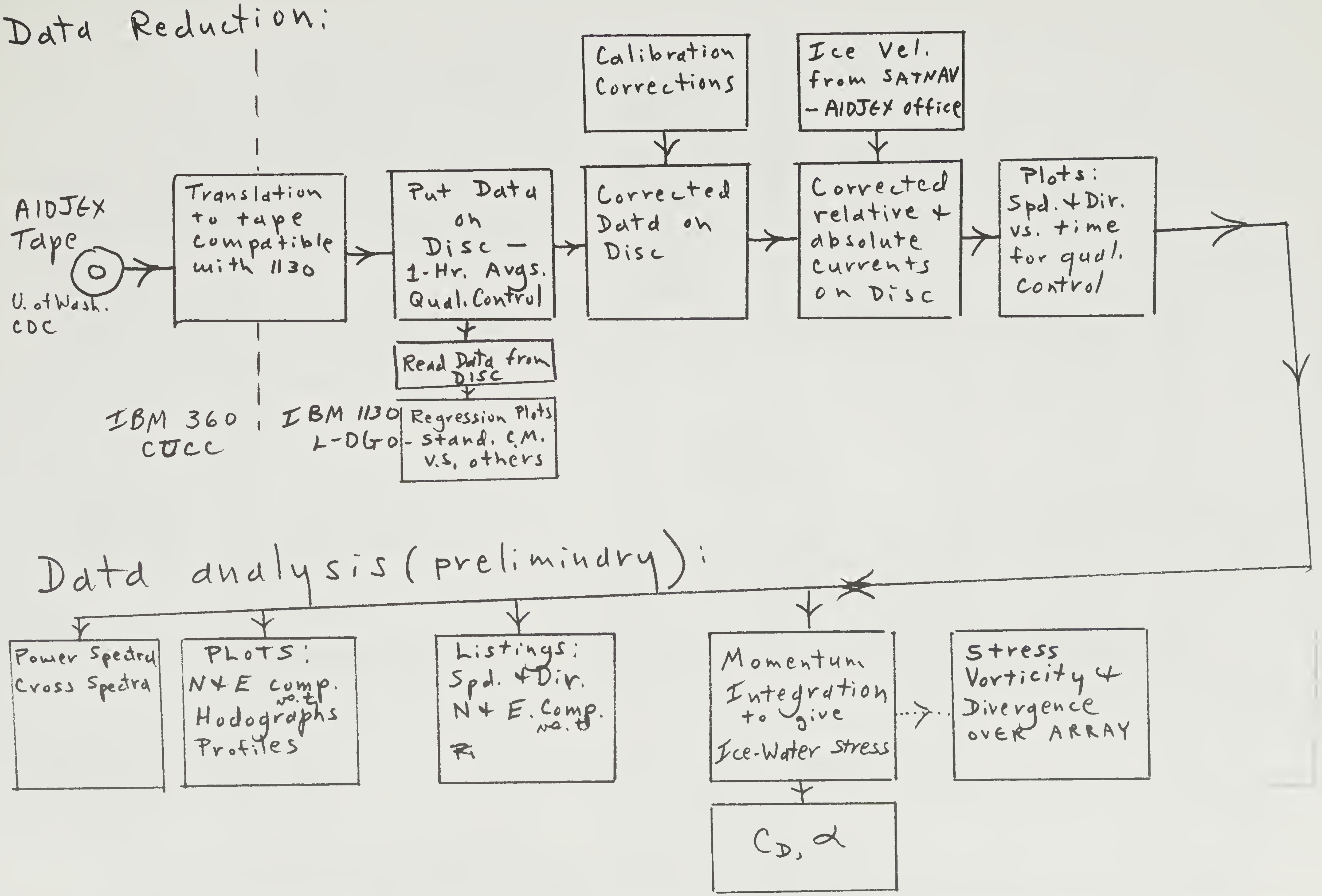


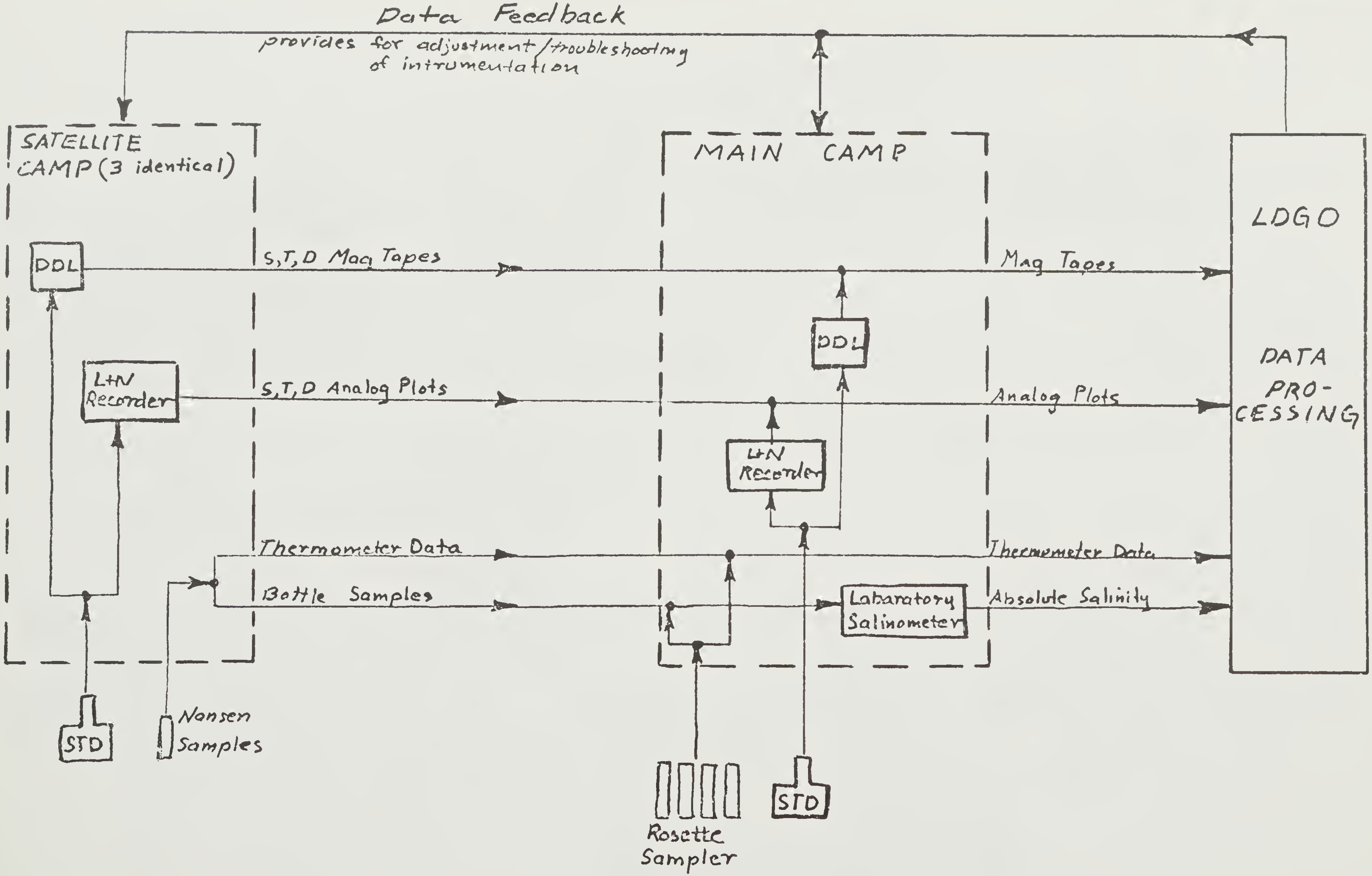
STD DATA PROCESSING, Block Diagram



Block Diagram of Current Meter Signal Flow for Satellite Camp.
Add two additional fixed C.M. at Main Camp.

Current Meter Data Flow





STD DATA FLOW, Block Diagram

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stations with separations of 100 km. Simultaneous measurements will be made at all four stations. Continuous current observations will be made at depths of 2 and 30 m. Current profiles from the surface to a depth of 200 m will be taken twice each day. Profiles of temperature and salinity will be taken twice each day also from the surface to 1,000 with Plessey salinity-temperature-depth recorders.